CHAPTER 11

Psychophysiological Assessment of PTSD

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Over the past 20 years, and particularly within the past 10 years, research has provided the foundation for a psychobiological characterization of posttraumatic stress disorder (PTSD). Much of this work has used measures of peripheral autonomic and muscular activity to assess key features of the disorder as specified in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV; American Psychiatric Association, 1994). More recently, there has been a notable increase in the use of measures of electrophysiological activity, specifically event-related potentials (ERPs), in the study of the disorder. Consistent with DSM criterion B5, the resulting findings have provided a relatively consistent picture of differential (e.g., greater) peripheral and central psychophysiological reactivity to stimuli related to an index traumatic event in individuals with PTSD that is not shown by individuals who experienced similar events but did not develop PTSD. Similarly, evidence from an array of psychophysiological studies supports the DSM-IV criterion D features of increased irritability or anger (D2), difficulty concentrating (D3), hypervigilance (D4), and exaggerated startle response (D5).

Research using psychophysiological measures also has examined the possibility that PTSD is characterized by persistently elevated levels of autonomic arousal. Other research has revealed psychophysiological characteristics that are not formally recognized as clinical or diagnostic features of PTSD but that are important to advancing our general understanding of the disorder. One of

the most consistent findings of this type has been that of exaggerated heart rate (HR) responses to sudden, loud tones in individuals with PTSD. Such findings suggest that PTSD is characterized by a heightened sensitivity to aversive stimulation.

Despite successful application of psychophysiological methods to the study of posttraumatic adjustment, the practical aspects of using these measures and methods for the diagnosis, evaluation, and treatment of PTSD remain obscure to most clinicians. Although a few researchers have begun to discuss potential clinical application of psychophysiological assessment (Allen, 2002; Beuzeron-Mangina, 2000; Pitman & Orr, 1993), such discussions of the technology and methods for psychophysiological measurement are likely to appear intimidating to the nonexpert. At minimum, descriptions of technical matters can make for laborious reading. In the past, equipping and maintaining a state-of-the-art psychophysiological laboratory has been expensive and time-consuming. Fortunately, personal computers and integrated circuitry have reduced costs and eased the burden of psychophysiological data management and quantification. It is no longer necessary for an individual to have a high level of expertise in psychophysiological technology and methods and extensive resources in order to take advantage of the benefits offered by psychophysiological methods.

It is important to recognize that the PTSD diagnosis is presently based on subjective information that is not necessarily comparable to information recorded directly from physiological systems. Self-reported physiological activity and emotional experience often do not correlate well with measured physiological responses. General research on autonomic perception and response covariation (Eifert & Wilson, 1991; Spinhoven, Onstein, Sterk, & LeHaen-Versteijnen, 1993; Tyrer, Lee, & Alexander, 1980) makes it clear that self-reports of psychophysiological reactivity are not interchangeable with observations or recordings of such activity. With regard to fear, Lang (e.g., 1985) has long noted that self-report and concurrent psychophysiological arousal seldom have more than 10% shared variance. Limited convergence between self-reported emotion and physiological measures adds complexity to the assessment of PTSD, but it can be readily managed by a multimodal approach (e.g., Malloy, Fairbank, & Keane, 1983) that looks for convergence among diverse measures and considers measures that diverge from each other as a source of potentially valuable information for case conceptualization.

This chapter begins with a brief, nontechnical overview of psychophysiological methods and issues. We then summarize current findings related to individual DSM diagnostic criteria for PTSD before addressing both psychophysiological predictors of risk and remission and the use of psychophysiology to monitor treatment process and outcome. These clinically oriented topics are followed by coverage of relevant basic processes related to unconditioned or defensive responding, habituation, conditionability, and emotional–motivational states. Next, we outline threats to the validity of psychophysiological assessment and identify some potential conceptual as-

pects of PTSD that psychophysiology might address. Finally, we present a proposal for incorporating objective psychophysiological reactivity into the diagnostic criteria. Hopefully, both researchers and clinicians will be encouraged to seriously consider the potential value of this methodology in their respective contexts.

A BASIC PRIMER ON PSYCHOPHYSIOLOGICAL MEASURES AND METHODS

Use of psychophysiology measurement in research or clinical practice requires a conceptual grasp of the systems and methods, even if true technical understanding and mastery are not essential. Some knowledge of physiology, biomedical equipment, and computers is important. Expert consultation and assistance is necessary for someone new to these methods, regardless of whether they are at the stage of planning for, collecting, or interpreting psychophysiological data. Paradoxically, engaging a consultant tends to increase the need for knowledge about psychophysiology rather than diminishing it. This knowledge allows for the sharing of a common language and conceptual understanding, which increases the likelihood of successful communication and collaboration.

This section provides a brief overview of some of the common measurement and interpretational issues related to the use of psychophysiological methods. An edited volume by Cacioppo, Tassinary, and Berntson (2000) provides a comprehensive and up-to-date discussion of psychophysiological theory, methodology, and analysis. This handbook is recommended as a resource for anyone, expert or novice, interested in psychophysiology.

Four Key Physiological Systems

Cardiovascular

Heart rate (HR) and blood pressure (BP) are the most commonly used cardiovascular measures. Heart rate can be obtained manually by palpating and counting the number of beats, or it can be obtained more reliably and with greater temporal resolution by recording the electrocardiogram (ECG) and either counting R-waves or measuring the time between them directly or by means of a cardiotachometer that translates time intervals to beats-per-minute equivalent values. Blood pressure can be recorded manually by the auscultatory (i.e., cuff and stethoscope) method used in routine physical examinations or by means of similar automated methods involving an inflatable cuff placed on an arm. Whether manual or automated, these methods produce intermittent readings. A recent innovation in psychophysiological recording allows for continuous recording of blood pressure and HR from a finger cuff.

Heart rate is typically expressed in beats per minute, whereas interbeat

interval or heart period is expressed in milliseconds. Blood pressure is expressed in millimeters of mercury pressure (Hg). The rate of sampling and level of precision required for obtaining HR and blood pressure data will be determined by the manner in which the signals are recorded, as well as by the issues addressed by the measures. For example, if one is interested in assessing resting level, samples might be obtained a few times per minute over an extended period of time, from several minutes to hours. However, if the objective is to evaluate responsivity to a brief stimulus, the recording interval should be relatively short. For HR, it would be desirable to capture each successive beat during the stimulus presentation, as well as for a short period immediately before and after the stimulus is presented. Although some HR responses to a stimulus may occur quickly, within 1–2 seconds, other responses may evolve more slowly, perhaps requiring 20–30 seconds to reach their peak.

Electrodermal

Sweat gland activity is perhaps the most widely studied response system, including measures of skin conductance (SC), resistance, and potential. Even though sweating serves a thermoregulatory function and is influenced by such factors as ambient temperature and humidity, when these factors are controlled there is a high correlation between output from the sympathetic nervous system (SNS) and SC responses (Wallin, 1981). In fact, Lang, Bradley, and Cuthbert (1990) have stated that "conductance change is a near-direct measure of general sympathetic nervous system activity" (p. 383). This specificity makes SC especially useful for assessing emotional arousal that is presumed to have a strong SNS component. Skin conductance is recorded by maintaining a very small constant voltage between two electrodes and measuring the variations in current that result from sweat gland activity in the underlying area. Conductance increases when the sweat ducts fill, membrane permeability changes, and sweat diffuses into the skin (Edelberg, 1972). Skin conductance is typically recorded from the fingers or palm of the nondominant hand through metal or silver/silver chloride electrodes. The contact area between the skin and electrode paste, as well as the distance between the two recording electrodes, will influence the value of SC level. For high-quality measurement, it is important to use an isotonic paste that approximates the salinity of sweat (see guidelines provided by Fowles et al., 1981) and not an electrolytic paste such as that used for ECG and other types of biological signal recording that is formulated to progressively reduce skin resistance (impedance) as it remains in contact with the skin.

Electromyographic

Muscle activity can be recorded through small surface electrodes placed over the muscle(s) of interest. Accurate location of the electrodes is very important so as to maximize detection of activity of the muscle group of interest and

minimize that associated with nearby muscles. A discussion of the technical aspects of electromyogram (EMG) recording and description of where to position electrodes for specific muscle groups of the face and body can be found in Cacioppo, Tassinary, and Fridlund (1990). Careful consideration should be given to selection of muscle sites and adherence to recommended procedures for electrode placement. For example, measuring frontalis EMG by locating electrodes over each eye (Andreassi, 1980), a common practice in biofeedback applications, is highly susceptible to nonselective muscle activity and is unsuitable for most nonbiofeedback applications. Recording EMG activity requires equipment that can amplify the microvolt signals and provide filtering of the raw signal so as to include the primary frequencies associated with muscle activity. It is usually desirable to rectify (make positive) and integrate (smooth) the raw EMG so that the signal more clearly reflects meaningful changes and is less sensitive to momentary fluctuations. Proper abrading of the recording site and use of an electrolytic paste are two important steps for reducing resistance in the skin and achieving high-quality EMG recordings.

Electrocortical

Electrocortical activity recorded in electroencephalograhic (EEG) and event-related potential (ERP) studies is measured by placing electrodes on the scalp at specific locations, and then amplifying and filtering the microvolt signals so that they are discriminated from background noise and reflect the process of interest (e.g., attention). Electrodes are commonly fitted inside an elasticized cap, much like a bathing cap, which positions and holds them at the correct locations on the head according to the standardized 10–20 international system (Jasper, 1958). The number of electrodes may range from as few as 10 to more than 100 depending on the particular application. Electrodes also are placed near the eyes so that vertical and horizontal eye movements can be detected. Muscle activity associated with movement of the eyes, as well as the head or neck, can introduce artifact into the EEG recording. Data from trials that include significant movement are usually eliminated from analyses or corrected using mathematical algorithms.

EEG studies of brain asymmetry and emotion typically involve continuous recording of electrocortical activity from opposing sites on each side of midline (e.g., F3 and F4, T3 and T4 of the 10–20 international system) under baseline or emotionally evocative conditions. Studies have focused almost exclusively on alpha activity (8–13 Hz) because this power band is assumed to be inversely related to general brain activation. Alpha power is derived using a fast Fourier transform, and values often are log-transformed to normalize the distribution. Most commonly, asymmetry index scores are calculated by subtracting alpha power recorded at the left electrode site from that recorded at the right site. Positive scores indicate greater alpha power at the right than the left electrode site, which is assumed to reflect greater left- than right-sided brain activation.

Methodologies for measuring ERP components involve averaging the EEG signal over many trials to improve signal-to-noise ratio, because most ERP components are relatively small compared with the background EEG activity. This is accomplished by repeated presentations of either one stimulus or one type of stimulus (e.g., a tone of a specific intensity and frequency or a set of words related to a traumatic event) and averaging the recorded epochs for trials of the same type. Signal recording is typically initiated prior to stimulus onset in order to establish a baseline that can be used as a point of reference for each recorded epoch. Adjustment relative to baseline involves centering the voltage on a mean of zero over the prestimulus sampling period and is accomplished by subtracting the average baseline voltage from each measurement point in the poststimulus sampling epoch. Like EEG studies, the electrical signals are digitally filtered, and trials free of excessive eye-movement artifact are retained for signal averaging. Peak ERP component amplitudes (i.e., the maximal voltage deflection identified in a designated latency range) and their corresponding latencies are then scored for each stimulus type. An ERP waveform consists of a series of positive and negative voltages that are characteristically labeled with "P" or "N," to denote whether they are positive or negative, along with a number to indicate the latency of the component's peak or their ordinal position in the waveform. For example, "P300" or "P3" is a positive-going component that occurs approximately 300 milliseconds, and is the third positive component, after stimulus onset. It is worth noting that the convention for visual display of these waveforms has positive components going downward and vice versa.

Personal computers have revolutionized EEG and ERP research because they can be programmed to handle nearly all of the otherwise time-intensive data management and scoring tasks. As computers become more powerful, new methods of assessing and depicting brain activity are becoming available, including topographical maps that produce pictures to concisely represent a composite of brain electrical activity. Despite these advances, anyone considering this type of measurement should be aware that the technology remains rather intricate, data scoring and management still can be time-consuming, and many of the scoring and interpretational issues are complex.

Two Key Measurement Issues

Measuring Resting and Prestimulus Levels

Most psychophysiological investigations assess resting levels at the beginning of the procedure as a reference point for comparison with subsequent values. It also is common to obtain additional baseline values from rest periods at points throughout the procedure as a means of tracking shifts in tonic arousal. A decision must be made regarding the optimal amount of time for stabilization and collection of initial resting-level data. A review of studies that collected resting HR levels by Hastrup (1986) noted a negative correlation be-

tween subsequent HR level and duration of the rest period, indicating that shorter rest periods yield higher HR levels. In general, it appears that 15 minutes may be optimal for initial stabilization before assessing basal HR level, although decisions about baseline length are best viewed as application specific. Considerations that influence the decision include the fact that overly long rest periods may result in boredom, restlessness, and even sleep, whereas overly brief rest periods will not allow sufficient time for physiological stabilization, especially if participants have been physically active prior to the rest (e.g., coming directly into the lab from outside activities).

Periodic sampling of resting baseline values throughout a recording session is important for determining general physiological trends or to provide reference values for calculating the magnitude of responses (e.g., to trauma-relevant stimuli). Because physiological levels can change over time, especially when a variety of stimuli or tasks are being presented, it often is desirable to obtain baseline or nontask comparison values that precede and are proximal to the target of interest (e.g., prior to presentation of a particular stimulus). Suitable reference levels may be obtained from relatively brief periods of recording if the individual is sitting quietly and is not extremely anxious. For example, in the studies of trauma-related imagery (e.g., Orr, Pitman, Lasko, & Herz, 1993), baseline data were collected for 30 seconds prior to each script and 1–3 minutes were between trials. In ERP research, electrocortical recording commonly begins 100 milliseconds or so prior to each stimulus presentation. The mean level during this baseline interval is subtracted from values during the remainder of the recording interval to provide baseline correction for each trial. Intervals between trials can be as short as 2 seconds for procedures that use ERP measures. Depending on the protocol and type of stimuli being used, as well as the particular measure(s) being recorded, more or less time between stimulus presentations may be needed to allow for stabilization.

Deciding How Many Measures to Record

The most frequently used indices of emotional arousal in psychophysiological studies of PTSD have been measures of peripheral autonomic activity (i.e., HR, SC, and BP). A number of studies also have used facial EMG to assess emotional reactivity, whereas relatively fewer studies have recorded cortical ERPs in order to evaluate cognitive processing in PTSD. The selection of measures generally is determined by the conceptual and theoretical issues to be addressed, but there are practical considerations as well. These include such issues as previous use and popularity, amount of technical expertise required for data collection and interpretation, availability of instrumentation, and expense.

There is ample evidence that measures are differentially sensitive to emotional and psychological states and behaviors. It is important to recognize that one measure cannot simply be substituted for another. Fowles (1980) in particular has explored some of the differential value of HR and SC as

psychophysiological indicators. His model proposes that HR will better index responding associated with active avoidance behavior, whereas SC will better index active inhibition. Although HR and SC can provide useful indices of general arousal, they are not necessarily informative about its valence (i.e., whether it is positive or negative). In contrast, measures of facial EMG activity may not index intensity very well, but they are particularly good at providing information about the valence of the emotional arousal (Fridlund & Izard, 1983). For example, an increase in zygomaticus major activity (the muscle group involved in smiling) is characteristic of a pleasant emotional experience, whereas increased corrugator activity (the muscle group involved in frowning) has been found to accompany a depressed mood (Sirota & Schwartz, 1982). Corrugator EMG is especially useful for discriminating between positively and negatively valenced emotions.

Finally, it is important to recognize that there often are differences between individuals in the relative degree to which responses appear in one system versus another (Stern & Sison, 1990). For example, exposure to a generic stressor such as mental arithmetic may produce an increase in HR and SC levels for some individuals, whereas other individuals will show change in one system but not the other, and still others may show small or no changes at all. Measurement of only a single system greatly increases the likelihood that reactivity will be underestimated or missed completely in individuals who happen to be more responsive in another system.

OVERVIEW OF PSYCHOPHYSIOLOGICAL EVIDENCE IN RELATION TO TRAUMA AND PTSD

Reactivity to Trauma-Related Cues: Criterion B5

Theoretically, the critical element in physiological response to trauma-related cues is activation of the memory network in which a traumatic event is encoded. Once such a memory is activated, emotions that are associatively linked with it also become activated, along with their accompanying physiological responses. Interestingly, physiological reactivity to trauma-related cues was moved from the category of arousal symptoms (criterion D6) as it appeared in DSM-III-R to the category of reexperiencing symptoms (criterion B5) in DSM-IV. This change is of conceptual significance because it recognizes physiological reactivity as a measure of the degree to which an event is emotionally reexperienced rather than as a pathological symptom indicative of generally heightened arousal. The revision also is supported by findings, discussed later, that demonstrate that increased physiological reactivity is relatively specific to trauma-related stimuli and does not appear to generalize to other (i.e., non-trauma-related) stressful or emotionally negative stimuli (Casada, Amdur, Larsen, & Liberzon, 1998; Orr et al., 1993; Pitman et al., 1990; Pitman, Orr, Forgue, de Jong, & Claiborn, 1987).

The Standardized Audiovisual Method of Assessment

The standardized approach involves presentation of a fixed set of stimuli, such as light flashes, combat sounds (mortar explosions or gunfire), and pictures of combat situations, while psychophysiological responses are recorded (e.g., Blanchard, Kolb, Gerardi, Ryan, & Pallmeyer, 1986; Dobbs & Wilson, 1960; Malloy et al., 1983; McFall, Murburg, Ko, & Veith, 1990). The intensity level of the auditory stimuli may be varied within the procedure, beginning at a low level of sound or trauma-relevant content and increasing to progressively higher levels. Responses to standardized neutral stimuli that are not related to the trauma (e.g., music or slides depicting outdoor scenes) provide a comparison for physiological reactivity specific to trauma-relevant content.

Reactivity to any stimulus format can be calculated as difference scores between periods with contrasting content. For example, if trauma-related auditory stimuli are interspersed with neutral stimuli (e.g., music), a response score can be computed by subtracting the physiological level during the neutral presentation of the neutral stimulus from that recorded during the trauma-related presentation. This difference score represents the individual's relative reactivity to the two stimuli, with a positive value indicating greater trauma-related reactivity. Conceptually, scores of this sort reflect excess (i.e., trauma-specific) reactivity by taking account of both individual differences in physiological characteristics (e.g., responsivity or baseline levels) and reactivity to the task itself (e.g., listening to sounds) that are extraneous to the quantity of interest.

The use of standardized stimuli to assess psychophysiological reactivity allows maximal control over the selection and presentation of the stimuli. Furthermore, each individual's reactivity is measured to the same set of cues. Thus differences in physiological reactivity are more readily attributable to individual differences in the emotional relevance of the stimuli. A limitation of the use of standardized stimuli, especially in studies of emotion, is that the selected stimuli may not match a particular individual's unique experience(s). This can result in less than optimal activation of the target emotion(s).

The Script-Driven Imagery Method of Assessment

The imagery-based approach is derived from procedures developed by Peter Lang and his colleagues for the study of fear and phobias (Cook, Melamed, Cuthbert, McNeil, & Lang, 1988; Lang, Levin, Miller, & Kozak, 1983; McNeil, Vrana, Melamed, Cuthbert, & Lang, 1993). Details of the methodology as applied to trauma-exposed individuals can be found in Pitman et al. (1987) and Orr et al. (1993). Briefly, the procedure involves preparing various scripts that portray actual or hypothetical experiences of the person being assessed, including the two most stressful trauma-related experiences they can recall. Other experiences may include stressful lifetime experiences not related

to the trauma, positive experiences, or neutral experiences, depending on the most relevant comparison for the question at hand. A written description of each personal experience is reviewed and edited to produce a script of about 30-second duration, composed in the second person, present tense. Standard scripts portraying various hypothetical experiences also are included and provide a means for comparing responses to stimuli that are the same for all individuals within or between studies. Scripts are recorded in a neutral voice for playback in the laboratory while psychophysiological activity is measured. Individuals are instructed to listen carefully during the playing of each script and to imagine them as vividly as possible. The reading and imagining of each script is followed by a period for relaxation, after which several self-reports are made on Likert-type scales. A response score is calculated for each physiological dependent variable, separately for each script, by subtracting the preceding baseline period value from the value during imagery.

An important feature of the script-driven-imagery method is its flexibility. Scripts can be tailored to capture an individual's unique experience of a traumatic event and can also be used to assess emotional reactivity to most any traumatic event. For example, a Vietnam veteran whose job was handling dead bodies in a morgue might be unresponsive to standard combat-related sights and sounds but prove highly reactive to a script describing the personally relevant experience of working in a morgue. The potential limitations of this method include its reliance on participants' ability to recall the events in question and their willingness to comply with instructions to vividly imagine the experiences. Failure in either regard can result in an underestimate of an individual's emotional reactivity.

Summary of Evidence for Trauma-Specific Responding

One of the most consistent findings is that psychophysiological reactivity to cues reminiscent of the traumatic event is heightened in individuals diagnosed with PTSD but not in trauma-exposed individuals who fail to meet PTSD diagnostic criteria (for reviews, see McFall, Murburg, Roszell, & Veith, 1989; Orr, Metzger, & Pitman, 2002; Prins, Kaloupek, & Keane, 1995; Shalev & Rogel-Fuchs, 1993). Studies that have examined psychophysiological reactivity to trauma-related cues are summarized in Table 11.1. A number of studies have presented standardized audiovisual cues to combat veterans. Typically, combat sounds, such as mortar explosions or gunfire, and pictures of combat situations both have produced larger responses in HR, BP, electrodermal activity, and forehead EMG in veterans with PTSD than in those without PTSD (Blanchard et al., 1986; Blanchard, Kolb, Pallmeyer, & Gerardi, 1982; Blanchard, Kolb, Taylor, & Wittrock, 1989; Casada et al., 1998; Dobbs & Wilson, 1960; Malloy et al., 1983; McFall et al., 1990; Pallmeyer, Blanchard, & Kolb, 1986). Standardized combat-related words also have produced larger SC responses in combat veterans with PTSD than in combat veterans with other psychiatric disorders (McNally et al., 1987). Although the majority of

TABLE 11.1. Studies That Have Examined Psychophysiological Reactivity to Trauma-Related Stimuli in Individuals with and without PTSD

Study	Sample gender and trauma type	Sample size	Measures on which PTSD > non-PTSD	Trauma cue format
Blanchard, Hickling, Buckley, Taylor, Vollmer, & Loos (1996)	♀ ♀ MVA	PTSD = 38 TC = 32 NC = 54	HR*, F-EMG, SBP, DBP	SDI, videotape
Blanchard, Hickling, Taylor, Loos, & Gerardi (1994)	♀ Combat	PTSD = 23 TC = 17 NC = 40	SC, HR*, F-EMG, SBP, DBP	SDI, videotape
Blanchard, Kolb, Gerardi, Ryan, & Pallmeyer (1986)	♀ Combat	PTSD = 57 TC = 34	HR*	Combat sounds
Blanchard, Kolb, Pallmeyer, & Gerardi (1982)	♀ Combat	PTSD = 11 NC = 11	SC, HR*, F-EMG*, SBP*, DBP	Combat sounds
Blanchard, Kolb, Taylor, & Wittrock (1989)	♀ Combat	PTSD = 59 TC = 12	HR*	Combat sounds
Carson et al. (2000)	♀ Women exposed to war zone trauma	PTSD = 17 TC = 21	SC*, HR*, LF-EMG*, C-EMG	SDI
Casada, Amdur, Larsen, & Liberzon (1998)	♀ Combat	PTSD = 15 TC = 10 NC = 11	SC, HR*, F-EMG†	Combat sounds
Davis, Adams, Uddo, Vasterling, & Sutker (1996)	♀ Combat	PTSD = 10 TC = 18	SC, HR, LF-EMG	SDI
Gerardi, Blanchard, & Kolb (1989)	♀ Combat	PTSD = 18 TC = 18	SR*, HR*, F-EMG*, SBP, DBP	Combat sounds
Keane et al. (1998)	♀ Combat	PTSD = 631+ TC = 319+	SC*, HR*, LF-EMG*, SBP, DBP*	SDI, audiovisual
Kinzie et al. (1998)	♀ Combat, refugees	PTSD = 38 TC =22 NC = 22	HR	Audiovisual
Lanius et al. (2001)	♀ ♀ Mixed trauma	PTSD = 9 TC = 9	HR*	SDI
Malloy, Fairbank, & Keane (1983)	♀ Combat	PTSD = 10 TC = 10	SR, HR*	Audiovisual

(continued)

TABLE 11.1 *(continued)*

Study	Sample gender and trauma type	Sample size	Measures on which PTSD > non-PTSD	Trauma cue format
McDonagh-Coyle et al. (2001)[a]	♀ Sexual abuse	*N* = 371	SC, HR*, LF-EMG†	SDI
McFall, Murburg, Ko, & Veith (1990)	♂ Combat	PTSD = 10 TC/NC = 11	HR*, SBP, DBP*	Audiovisual
McNally et al. (1987)	♂ Combat	PTSD = 10 TC = 10	SC*	Words
Orr, Lasko, et al. (1998)	♀ Sexual abuse	PTSD = 29 TC = 18	SC, HR*, LF-EMG, C-EMG*	SDI
Orr, Pitman, Lasko, & Herz (1993)	♂ Combat	PTSD = 8 TC = 12	SC*, HR*, LF-EMG, C-EMG	SDI
Pallmeyer, Blanchard, & Kolb (1986)	♂ Combat	PTSD = 12 TC = 10 NC =5	HR*, SC*, F-EMG, SBP*, DBP*	Combat sounds
Pitman et al. (2001)	♀ Breast cancer	PTSD = 5 TC = 25	SC*, HR*, LF-EMG, C-EMG*	SDI
Pitman et al. (1990)	♂ Combat	PTSD = 7 TC = 7	SC*, HR, LF-EMG*	SDI
Pitman et al. (1987)	♂ Combat	PTSD = 18 TC = 15	SC*, HR, LF-EMG*	SDI
Shalev, Orr, & Pitman (1993)	♂ ♀ Mixed trauma	PTSD = 13 TC = 13	SC, HR*, LF-EMG*	SDI
Wolfe et al. (2000)	♀ Women exposed to war zone trauma	PTSD = 8 TC = 20	SC*, HR, SBP*, DBP	Audiovisual

Note. SR, skin resistance; SC, skin conductance; HR, heart rate; F-EMG, forehead EMG; LF-EMG, lateral frontalis EMG; C-EMG, corrugator EMG; TC, trauma-exposed control group; NC, normal (non-trauma-exposed) control group; MVA, motor vehicle accident; SDI, script-driven imagery; SBP, systolic blood pressure; DBP, diastolic blood pressure.

[a]A correlational approach was used in this study.

* $p < .05$; † $p < .10$.

studies using standardized audiovisual cues have involved male military veterans, recent research also has demonstrated heightened psychophysiological reactivity in female veterans and in veterans' service organization volunteers with PTSD related to their experiences during the Vietnam War (Wolfe et al., 2000). Only one published study did not find larger responses to videotaped scenes of the Vietnam War in veterans with than without PTSD (Kinzie et al., 1998). However, even this study found a larger HR response to videotaped scenes of a Cambodian refugee camp in Cambodians with PTSD than in those without PTSD. Overall, the pattern of findings is extremely consistent.

Studies that have used individually tailored imagery scripts as the means for cue presentation also have found larger SC, HR, and/or facial EMG (lateral frontalis) responses during recollection of trauma-related experiences in individuals with PTSD than in those without PTSD. This trauma-specific reactivity has been found with male Vietnam, World War II, and Korean combat veterans (Orr et al., 1993; Pitman et al., 1990; Pitman et al., 1987), adult females with a history of childhood sexual abuse (McDonagh-Coyle et al., 2001; Orr, Lasko, et al., 1998), female nurse veterans who witnessed injury or death during military service in Vietnam (Carson et al., 2000), and breast cancer survivors (Pitman et al., 2001), as well individuals exposed to other civilian traumatic events (Blanchard et al., 1996; Blanchard, Hickling, Taylor, Loos, & Gerardi, 1994; Shalev, Orr, & Pitman, 1993). The findings for Vietnam veteran nurses and breast cancer survivors are of particular interest as evidence consistent with the position taken in DSM-IV concerning the ability of "witnessing a traumatic event" and "being diagnosed with a life-threatening illness" to act as potential causes for PTSD. Finally, a large multisite study involving more than 1,300 male Vietnam veterans applied both standardized audiovisual and script-driven imagery procedures in an examination of combat-related PTSD (Keane et al., 1998). Results of this study replicated findings of heightened physiological reactivity in combat veterans with PTSD, although the magnitude of the effect is somewhat smaller than that obtained in smaller studies.

Findings from two studies stand in contrast to those demonstrating the relative specificity of heightened psychophysiological reactivity to trauma-related cues in individuals with PTSD. A study by Beckham and colleagues (Beckham et al., 2002) observed larger systolic blood pressure and a trend toward larger HR responses in Vietnam combat veterans during recollection of a past experience of anger than in veterans without PTSD. This finding is not surprising in light of previous evidence for greater anger and hostility shown by individuals with PTSD (e.g., Beckham, Moore, & Reynolds, 2000). In a second study, male and female Cambodian refugees with PTSD from prolonged and intense trauma showed elevated HR responses, relative to controls without trauma, to videotaped scenes of a Cambodian refugee camp but also to scenes of an auto accident, domestic violence, the Vietnam War, and a hurricane (Kinzie et al., 1998). The reason for generalized reactivity in the Cambodians with PTSD is not clear, but one possible explanation is the use of a

finger pulse plethysmograph to measure HR. This instrument can be susceptible to artifact produced by muscle movement. Consistent with this possibility, behavioral observations indicated that the Cambodian refugees with PTSD reacted more strongly across scenes.

This body of evidence supports the idea that physiological responses can provide an index of the emotional experience associated with reactivation of memory for a traumatic event. An extension of this idea is that the presence of clinical pathology can be inferred from reactivity to trauma-related cues. Several investigators (e.g., Blanchard, Kolb, & Prins, 1991; Malloy et al., 1983; Orr et al., 1998; Pitman et al., 1987; Shalev et al., 1993) have attempted to use one or more indices of psychophysiological reactivity as a marker for PTSD. These diagnostic applications have produced sensitivity values in the range of 60–90% and specificity values of 80–100%.

Reactivity to Generic Stressors

Although individuals with PTSD respond with increased reactivity to trauma cues, they appear to show relatively normal levels of responding to generic stressors unrelated to trauma. For example, studies measuring autonomic responses while performing mental arithmetic have reported comparably large (Blanchard et al., 1986; Orr, Meyerhoff, Edwards, & Pitman, 1998) and even somewhat smaller (Keane et al., 1998; McDonagh-Coyle et al., 2001) responses in individuals with PTSD than in those without. A purely physical stressor, orthostatic challenge, also produced comparably large increases in HR and BP in groups with and without PTSD (Orr, Meyerhoff, et al., 1998). However, individuals with PTSD are more physiologically reactive to aversive stimuli, such as loud sounds or mild electric shock (e.g., Casada et al., 1998). Increased reactivity to aversive unconditioned stimuli such as loud noises or shock could represent a heightened sensitivity of the nervous system, of which sensitization of the amygdala may play a central role (see Pitman, Shalev, & Orr, 1999).

Use of Neuroimaging Methods

Recently, challenge studies have begun to employ more sophisticated measures of brain activation, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) to identify the neural circuitry associated with increased responsiveness to trauma cues. Some of these studies have incorporated peripheral psychophysiological measures, including HR, SC, and facial EMG, to provide concurrent validation of emotional responding to the challenge task. Similar to findings described previously, these studies have reported increased HR responding during traumatic stimulation in individuals with PTSD compared with individuals without PTSD (Lanius et al., 2001; Shin et al., 1999) or with baseline-neutral conditions (Pissiota et al., 2002; Rauch et al., 1996). The integration of neuroimaging and psycho-

physiological assessment is an important direction for future research, as the simultaneous measurement of regions of brain activation and psychophysiological responding should ultimately improve our understanding at both levels.

Numbing of General Responsiveness: Criteria C4–6

Despite clear evidence for heightened physiological reactivity to trauma reminders, many individuals with PTSD also report a diminished ability to experience emotions. This complaint is reflected in the DSM-IV criteria for PTSD that address symptoms of disinterest (C4), detachment (C5), and restricted range of affect (C6). Theorists have hypothesized that the hyperarousal and numbing symptoms of PTSD are inversely related and are characterized by alternating periods of intense reexperiencing and negative arousal followed by intervals of dampened affective responsivity (Herman, 1992; Horowitz, 1986; van der Kolk, 1987; van der Kolk, Greenberg, Boyd, & Krystal, 1985).

Litz (1992) also proposed that emotional numbing in PTSD is phasic but conceptualized the phenomenon as a transient depletion or reduction in the capacity for *positive* emotion that follows and is tied to episodes of intense reexperiencing and trauma-related arousal. In other words, Litz's model posits that affective abnormalities in PTSD are: (1) secondary to either acute or sustained activation of trauma-related emotional responses and (2) reflected in hyporeactivity to stimuli that normally evoke a positive or appetitive hedonic response. Litz also proposed that (3) exposure to trauma-related cues primes the psychobiological systems underlying aversive emotional states, resulting in facilitation of subsequent defensive responses and reactivity to unpleasant stimuli. Preliminary support for the first two of these propositions has been provided by evidence that self-reports of emotional numbing symptoms are most strongly predicted by hyperarousal symptoms (Litz et al., 1997; Flack, Litz, Hsieh, Kaloupek, & Keane, 2000) and by laboratory data showing that activation of a trauma-related emotional response produced phasic reductions in the expression of positive affect in individuals with PTSD (Litz, Orsillo, Kaloupek, & Weathers, 2000).

In the Litz et al. (2000) study, combat veterans with and without PTSD viewed emotionally evocative pictures before and after exposure to a combat-related audiovisual presentation while their self-report and physiological responses, including facial EMG, were recorded. Results revealed that the two groups exhibited equivalent patterns of affective response prior to the trauma-related challenge, yet after that manipulation, participants with PTSD exhibited suppressed zygomaticus EMG (i.e., smile) responses during viewing of pleasant images relative to controls. A follow-up study by Miller and Litz (in press) replicated the equivalent patterns of psychophysiological response under baseline conditions in veterans with and without PTSD. However, in this study, individuals with PTSD showed facilitation of negative emotional responses after exposure to trauma-related cues without evidence of change in

indicators of positive emotion. Although the results of the two studies diverge with regard to the acute consequences of activating trauma-related emotions, they are broadly consistent with models that emphasize the phasic nature of affective disturbance in individuals with PTSD.

Sleep Disturbance: Criterion D1

Although there is extensive research and clinical literature regarding psychophysiological assessment of sleep and sleep problems (see Pivik, 2000), PTSD-related work of this type is only now beginning to emerge. For example, Woodward, Murberg, and Bliwise (2000) measured EEG during sleep and noted a trend toward reduced low-frequency power during non-rapid-eye-movement sleep in veterans with combat-related PTSD compared with controls without PTSD. A difference also was noted for the ratio of rapid eye movement (REM) to non-REM beta-band EEG between individuals with and without PTSD. A recent study of the effects of cognitive behavioral therapy noted a reduction in heart rate variability (HRV) during REM sleep in 5 patients who improved with therapy compared with an increase in HRV in the single patient who did not improve (Nishith et al., 2003). These pilot findings suggest that improvement in PTSD symptoms may be associated with a reduction in HRV. The application of psychophysiological measures and methods to PTSD-related sleep disturbances is a promising direction for future research.

Irritability or Anger: Criterion D2

Findings from a number of studies using self-report measures (Beckham, Feldman, et al., 2000; Butterfield, Forneris, Feldman, & Beckham, 2000; Lasko, Gurvits, Kuhne, Orr, & Pitman, 1994) support the DSM criterion regarding heightened anger and hostility as a feature of PTSD. One noteworthy study recently examined whether individuals with PTSD also show increased psychophysiological reactivity during recollection and reliving of a past personal anger-provoking situation. Beckham et al. (2002) measured HR and BP in combat veterans with and without PTSD when cued to relive a memory in which they felt angry, frustrated, or upset with another person. Veterans with PTSD were quicker to indicate the onset of anger and produced larger HR and diastolic BP responses while reliving their anger situations. These findings raise the possibility that at least some subpopulations with PTSD may be characterized by heightened physiological reactivity to stimuli associated with anger, in addition to stimuli related to the index traumatic event.

Difficulty Concentrating: Criterion D3

Several studies have reported abnormalities in an ERP component linked to attentional processing in PTSD, thereby providing electrophysiological evidence for the DSM-IV symptom of disturbed concentration. Specifically, re-

searchers have used the auditory oddball procedure to examine P3 responses in individuals with PTSD. The auditory oddball is the most common procedure for eliciting the P3 response and has been widely used in the study of attention in clinical disorders (Polich & Herbst, 2000). In this procedure, individuals listen to a series of infrequently presented "target" tones that are interspersed among highly frequent "common" tones and infrequent "distractor" tones. The tones differ in pitch, with the target tone often having the highest (e.g., 2000 Hz), the distractor tone having the lowest (e.g., 500 Hz), and the common tone having an intermediate (e.g., 500 Hz) pitch. Participants are instructed to sit quietly with their eyes open and to press a button (or keep a mental count) in response to target tones, while ignoring all other tones. During performance of this task, the individual's ERPs are recorded during a 1-second interval starting 100 milliseconds prior to tone onset. The P3 response is scored as the most positive point of electrical activity in the time window between approximately 300 and 500 milliseconds following tone onset. In normal individuals, the P3 response to the target stimulus at the midline parietal (Pz) recording site is larger relative to the P3 response to common stimuli and is often larger than the response to distractor stimuli. The relative amplitude of the P3 response reflects task relevancy (i.e., importance) and infrequency (i.e., low probability) of the target stimulus and is widely presumed to index the amount of attentional resources directed at the eliciting stimulus. In line with findings reported for several other clinical disorders, samples of men and women with PTSD have produced smaller P3 response amplitudes to target stimuli than have their respective comparison groups, suggesting that they have increased difficulty concentrating (Charles et al., 1995; Felmingham, Bryant, Kendall, & Gordon, 2002; Galletly, Clark, McFarlane, & Weber, 2001; McFarlane, Weber, & Clark, 1993; Metzger, Orr, Lasko, Berry, & Pitman, 1997; Metzger, Orr, Lasko, & Pitman, 1997).

It is noteworthy that this ERP indicator has not been found in PTSD samples containing individuals on psychoactive medications (Kimble, Kaloupek, Kaufman, & Deldin, 2000; Metzger, Orr, Lasko, & Pitman, 1997), as might be expected if one effect of medication is to improve attention and concentration. Neylan et al. (2003) did not find smaller P3 response amplitudes to auditory and visual targets in a sample of male Vietnam veterans that included a mixture of medicated and unmedicated individuals, nor were there differences in P3 between medicated and unmedicated participants. Interpretation of these findings is complicated by a strikingly small mean P3 response for the group without PTSD, compared with previously published P3 means for control groups. Finally, a recent study of unmedicated female veterans who had served as military nurses in Vietnam demonstrated significantly *larger* P3 amplitudes to target stimuli in those with PTSD than in those without the disorder (Metzger et al., 2002). This is a curious finding and difficult to reconcile given that P3 amplitude abnormalities in clinical populations are typically associated with reduced responses. One possible explanation is that the larger P3 responses in the nurse veterans with PTSD represent increased attention and concentration used to compensate for limitations associated with having PTSD.

Hypervigilance: Criterion D4

Psychophysiological support for the DSM-IV symptom of hypervigilance recently has been provided by studies using both peripheral and central measures. Two studies of conditionability in PTSD (Orr et al., 2000; Peri, Ben-Shakhar, Orr, & Shalev, 2000) found that individuals with PTSD showed larger SC-orienting responses to initial presentations of the to-be-conditioned neutral stimulus (i.e., slides of colored circles), suggesting increased vigilance toward novel stimuli. A study of motor vehicle accident victims found that those with PTSD showed a greater number of SC-orienting responses to both neutral and threatening words, supporting the possibility of a generally heightened orienting response among these individuals (Bryant, Harvey, Gordon, & Barry, 1995).

Support for increased orienting responses in women with PTSD also is provided by an ERP study in which they showed a larger negative-going deflection when a novel stimulus is presented within a repeated stimulus chain (so-called mismatch negativity; Morgan & Grillon, 1999). Likewise, a relatively increased frontal P3 response amplitude to novel distractor stimuli has been reported for male Vietnam combat veterans (Kimble et al., 2000). Such enhanced cortical responses to novel stimuli may index the clinical symptoms of hypervigilance. However, a recent study that compared frontal P3 responses to both novel auditory and visual stimuli between male Vietnam combat veterans with and without PTSD did not find evidence supporting increased orienting in PTSD (Neylan et al., 2003).

Tendency to suppress or reduce an early positive ERP response (i.e., P50) to the second of two stimuli presented in close temporal proximity can be interpreted as an indicator of vigilance. Four studies have examined this effect, indexed as the ratio of P50 responses to a series of paired clicks in individuals with PTSD. In normal individuals, the amplitude of the P50 response to the second click of a pair is appreciably smaller than the response amplitude to the first click. This reduction presumably is the result of a central inhibitory function or sensory gating response at the neuronal level. Both male Vietnam combat veterans (Gillette et al., 1997; Neylan et al., 1999) and female rape victims (Skinner et al., 1999) with PTSD have failed to show a reduction in P50 response amplitude to the second of the paired clicks, resulting in abnormally large P50 ratios. One study of female military nurses who were veterans of war in Vietnam (Metzger et al., 2002) failed to find support for sensory gating abnormalities specific to PTSD, although this study did find that P50 ratios were related to measures of general psychopathology. This finding is consistent with evidence that P50 ratios are abnormally increased in several other clinical disorders, particularly schizophrenia.

Finally, researchers have measured ERP P3 responses to combat-related words (Stanford, Vasterling, Mathias, Constans, & Houston, 2001) and pictures (Attias, Bleich, Furman, & Zinger, 1996; Attias, Bleich, & Gilat, 1996; Bleich, Attias, & Furman, 1996) in the context of an emotional oddball paradigm. Modeled after the three-tone oddball procedure, this procedure used

trauma-related pictures or words as infrequent, to-be-ignored "distractors" that were interspersed among common (e.g., home furnishings) and target (e.g., domestic animals) stimuli. In each study, combat veterans with PTSD produced larger P3 waveform components to the trauma-related stimuli than did veterans without PTSD. In similar studies of normal individuals, the P3 has been shown to be sensitive to the intrinsic emotional or informational value of a stimulus and is presumed to provide an index of the attentional resources devoted to processing the stimulus. Importantly, combat veterans with PTSD do not show larger P3 response amplitudes to social threat words (Stanford et al., 2001), suggesting that the involuntary attentional bias is specific to trauma-related cues, perhaps due to their increased emotional significance, and does not generalize across all negative emotional cues.

The P3 response to trauma-related stimuli recorded at the parietal site has been found to correctly classify 90% of Israeli combat veterans with PTSD and 85% of the veterans without PTSD (Attias, Bleich, & Gilat, 1996). This is consistent with the sensitivity and specificity values obtained for autonomic measures and supports the potential diagnostic utility of ERP measures. To date, only one published study has not found evidence of larger P3 amplitude responses to trauma-related words in PTSD. In this instance, a mixed trauma group with PTSD showed smaller P3 amplitudes across neutral, positive, and trauma-related words presented in the context of an emotional Stroop color-naming task (Metzger, Orr, Lasko, McNally, & Pitman, 1997). The smaller P3 amplitudes are suggestive of attentional difficulties (e.g., concentration difficulties, as discussed previously) and might reflect poorer performance due to the more difficult than usual format of the Stroop task in this study, which entailed indicating the color of words (via button press) while ignoring word meaning. Importantly, although participants with PTSD did not show selective differences in P3 amplitudes to trauma-related words, behaviorally they did take longer to indicate the color of trauma-related words, consistent with the presence of a cognitive bias for trauma-related information. Because participants are asked to ignore all nontarget stimuli in each of these tasks, both larger P3 amplitudes and longer color-naming reaction times appear to reflect an automatic, involuntary cognitive response. Therefore, these findings suggest that PTSD is characterized by "selective cognitive sensitivity" to stimuli reminiscent of the traumatic event (Stanford et al., 2001), which might be a component of a more general hypervigilant state.

Exaggerated Startle Response: Criterion D5

Exaggerated startle responding has been recognized as a core subjective symptom of posttrauma reactions since the earliest descriptions of combat soldiers suffering adverse effects of exposure to the stress of combat (Cambell, 1918; Grinker & Spiegel, 1945; Southard, 1919). Kardiner (1941), one of the first to systematically describe the syndrome, considered exaggerated startle to be a central element of the disorder which he related to the hyperarousal symptoms. Recent empirical studies have confirmed the association between self-

reports of exaggerated startle, PTSD, and the hyperarousal symptoms. Indeed, startle may be one of the most reliably reported symptoms of the disorder. For example, Davidson, Hughes, Blazer, and George (1991) found that exaggerated startle was endorsed by 88% of participants with a diagnosis of PTSD, making it the second most commonly reported symptom following re-experiencing of the trauma. Similarly, Pynoos et al. (1993) examined the strength of the association between each PTSD symptom and diagnostic status using discriminant function analysis and found that self-report of exaggerated startle accounted for the second largest proportion of variance in diagnostic status, preceded only by intrusive thoughts. Likewise, Meltzer-Brody, Churchill, and Davidson (1999) found that exaggerated startle was the PTSD symptom that best differentiated individuals who met full diagnostic criteria from those who did not.

There also is evidence based on self-reports suggesting that exaggerated startle is one of the first symptoms to emerge following trauma exposure. Among survivors of an industrial disaster, Weisaeth (1989) found that intense startle was the most commonly reported PTSD symptom within 1 week of the disaster, being endorsed by 80% and 86% of participants with moderate and high levels of exposure to the accident, respectively. Similarly, Southwick and colleagues (Southwick et al., 1993; Southwick et al., 1995) examined the development of PTSD symptoms over time in two units of Gulf War veterans and found that increased startle was the most frequently reported PTSD symptom at 1 month, the third most common symptom at 6 months, and the second most frequently endorsed symptom 2 years after returning from the war.

From a psychophysiological perspective, the startle response is a constellation of defensive reflexive motor movements, phasic autonomic responses, and voluntary orienting movements that occur (in that temporal order) in response to any sudden, intense change in stimulus intensity. The reflexive component of the reaction begins with an eyeblink between 20 and 50 milliseconds after onset of a startle-eliciting stimulus and spreads distally to produce upper-limb, truncal, and lower-limb flexion. The reflex follows a similar, though not identical, pattern between individuals and is distinguished from the subsequent autonomic nervous system responses (e.g., phasic heart rate acceleration and deceleration; SC increases) and voluntary motor movements (i.e., postural adjustments and orienting toward a stimulus source) that have a longer latency and are characterized by greater interindividual variation in form and duration (Howard & Ford, 1992).

Generating and measuring the human startle response is relatively simple. It is usually accomplished by exposing individuals to stimuli that have an appropriate combination of (high) intensity and (sudden) onset and then quantifying the magnitude of muscular or autonomic reactivity they produce. Acoustic stimuli, either brief bursts of white noise or pure tones, with intensities ranging from 85 to 116 dB, are commonly used for generating startle responses in the laboratory. In humans, the startle reflex is typically measured from EMG recordings of the contraction of the orbicularis oculi muscle that

subserves eyeblink response, an index that is considered the most reliable and persistent component of the startle complex (Landis & Hunt, 1939). Eyeblink responses are typically elicited by an acoustic stimulus (e.g., a brief burst of loud white noise presented over headphones), although visual (e.g., light flashes) and tactile stimuli (e.g., air puffs) can also be used. The orbicularis oculi EMG signal typically is scored off-line using mathematical algorithms or visual inspection to determine the onset latency and magnitude, in microvolts, of the muscle contraction.

In contrast to clear and consistent evidence regarding subjective startle as a core feature of PTSD, laboratory evidence for exaggerated startle is equivocal. As summarized in Table 11.2, 19 published laboratory studies have compared the acoustic eyeblink startle reflex in individuals with and without PTSD. Data analyses in all of these studies have focused on indices of baseline or overall startle amplitude. Some also examined group differences in habituation of the startle response or included more complex manipulations (prepulse inhibition, e.g., Grillon, Morgan, Southwick, Davis, & Charney, 1996; fear potentiation of startle, e.g., Grillon, Ameli, Goddard, Woods, & Davis, 1994). Overall, 11 out of the 19 studies have reported significant blink-amplitude differences between individuals with and without PTSD. This trend suggests that heightened EMG-indexed startle is associated with PTSD but also that there may be one or more important moderating or mediating factors that have not been consistently addressed by procedures used in past startle studies.

What might account for the discrepancy between findings from self-report versus psychophysiological studies of startle? One theoretically and biologically substantive possibility is that exaggerated startle in PTSD is a context- or state-dependent phenomenon related to anxiety (Grillon & Morgan, 1999; Grillon, Morgan, Davis, & Southwick, 1998b). This hypothesis follows from research by Davis and colleagues (e.g., Davis, Walker, & Lee, 1997, 1999) on the neurobiology of fear, anxiety, and startle. The evidence shows that, although amplitude of the startle response is potentiated by both exposure to contextual threat (i.e., anxiety, as in returning to the location of previous aversive conditioning) and explicit threat (i.e., fear, as in exposure to a conditioned stimulus signaling imminent shock), these responses are mediated by different neurobiological systems. Specifically, the response conditional to contextual threat is mediated by the corticotropin-releasing hormone (CRH) system of the bed nucleus of the stria terminalis, whereas the response conditional to explicit threat cues is mediated by the central nucleus of the amygdala.

The body of findings based on humans suggests that exaggerated startle in PTSD is an anxiety-based or context-dependent phenomenon. It appears that differences between groups with and without PTSD are most reliably observed under test conditions involving distal anticipation of an aversive stimulus and are not observed under conditions involving proximal threat. As shown in Table 11.2, all 4 studies involving contextual anxiety cues (e.g., an-

TABLE 11.2. Studies That Have Examined Exaggerated Startle, As Measured from the Eyeblink Response, in Individuals with and without PTSD

Study	Sample gender and trauma type	Sample size	Startle amplitude for PTSD > non-PTSD	Procedures create aversive context
Butler et al. (1990)	♂ Combat	PTSD = 20 Non = 18	Yes	No
Cuthbert et al. (2003)	♂ ♀ Assorted traumas	PTSD = 22 Non = 108	No	No
Grillon & Morgan (1999)	♂ Combat	PTSD = 13 Non = 14	Yes	Yes
Grillon, Morgan, Davis, & Southwick (1998a)	♂ Combat	PTSD = 19 Non = 13	Yes	No
Grillon, Morgan, Davis, & Southwick (1998b)	♂ Combat	PTSD = 34 Non = 31	Yes	Yes
Grillon, Morgan, Southwick, Davis, & Charney (1996)	♂ Combat	PTSD = 21 Non = 27	No	No
Ladwig et al. (2002)	♂ ♀ Cardiac survivors	PTSD = 11 Non = 19	Yes	No
Medina, Mejia, Schell, Dawson, & Margolin (2001)	♀ Domestic abuse	PTSD = 7 Non = 39	No	No
Metzger et al. (1999)	♀ Childhood sexual abuse	PTSD = 21 Non = 13	No	No
Morgan, Grillon, Southwick, Nagy, et al. (1995)	♂ Combat	PTSD = 18 Non = 11	Yes	Yes
Morgan, Grillon, Southwick, Davis, & Charney (1995)	♂ Combat	PTSD = 9 Non = 10	Yes	Yes
Morgan, Grillon, Southwick, Davis, & Charney (1996)	♂ Combat	PTSD = 10 Non = 22	Yes	No
Morgan, Grillon, Lubin, & Southwick (1997)	♀ Sexual assault	PTSD = 13 Non = 16	Yes	No
Orr, Lasko, Shalev, & Pitman (1995)	♂ Combat	PTSD = 37 Non = 19	Yes	No
Shalev, Peri, Orr, Bonne, & Pitman (1997)	♂ ♀ Assorted traumas	PTSD = 30 Non = 28	Yes	No
Orr, Solomon, et al. (1997)	♂ Combat	PTSD = 19 Non = 74	No	No

(continued)

TABLE 11.2. *(continued)*

Study	Sample gender and trauma type	Sample size	Startle amplitude for PTSD > non-PTSD	Procedures create aversive context
Ross et al. (1989)	♂ Combat	PTSD = 9 Non = 9	No	No
Shalev et al. (2000)	♂ ♀ Assorted traumas; mainly MVA	PTSD = 36 Non = 182	No	No
Shalev, Orr, Peri, Schreiber, & Pitman (1992)	♂ ♀ Unspecified trauma	PTSD = 14 Non = 34	No	No

ticipation of a threatened shock or needle stick) found significant group differences in baseline startle amplitude, whereas only 7 of 14 studies that lack explicit anticipation of aversive stimulation found such differences. More direct evidence has been provided by Grillon et al. (1998b), who examined startle responses in veterans with and without PTSD during an initial laboratory session that involved no aversive manipulation, followed several days later by startle testing during an aversive conditioning procedure that involved anticipation of a mild shock. Significant group differences in baseline startle amplitude were observed only during session 2, suggesting that group effects were linked to the anxiogenic context in which the shock conditioning took place. No group differences in the fear response to presentation of conditioned threat cues (i.e., a CS+) were found, consistent with the possibility that exaggerated startle in PTSD is linked exclusively to the neurobiological system underlying contextual anxiety and not to the system underlying fear.

A recent study by Pole, Neylan, Best, Orr, and Marmar (2003) found that PTSD symptom severity was positively related to SC response magnitude under low and moderate but not high (i.e., imminent) threat conditions. Eyeblink EMG response magnitude was positively related to symptom severity only under the moderate threat condition. When the physiological responses measured under low threat were added to a regression model predicting PTSD symptom severity, they explained an additional 22% of the variance beyond the 11% explained by self-reported startle alone. This finding is especially interesting because it suggests that self-reported startle and physiological measures of startle may be tapping different aspects of PTSD symptom severity.

Persistent Autonomic Arousal

A chronic stress-related disorder such as PTSD has potential to produce long-term dysregulation of sympathetic activity that would be manifested as, for example, persistent elevations in BP, HR, and SC levels. Some of these alter-

ations are recognized as precursors to serious health consequences, including hypertension and cardiovascular disease (Blanchard, 1990). In fact, a recent study showed evidence of increased atrioventricular conduction deficits, nonspecific ECG abnormalities, and infarctions in a group of 54 Vietnam veterans with combat-related PTSD (Boscarino & Chang, 1999). The presence of these cardiovascular abnormalities appeared unrelated to comorbid depression and other anxiety disorders, alcohol consumption, smoking, demographic variables, body mass, and so forth.

Questions about elevated psychophysiological levels in PTSD typically have been addressed through second-order analyses applied to data collected during challenge studies involving trauma-related or threat (i.e., electric shock) tasks. Physiological levels are recorded while subjects sit quietly prior to exposure to the primary study stimuli or tasks. Some studies have reported elevated HR, BP, and SC levels at rest in participants with PTSD compared with controls (Blanchard, 1990; Casada et al., 1998; Kinzie et al., 1998; Orr et al., 2000), whereas a number of other studies have not (Blanchard et al., 1994; Blanchard et al., 1986; McFall et al., 1990; Orr et al., 1993; Pitman et al., 1990; Shalev et al., 1993). Relative elevations in HR and BP levels, recorded manually by a triage nurse, also have been found in a retrospective examination of the medical records of Vietnam combat veterans with PTSD who were seeking medical or psychiatric help at a VA hospital, compared with similar help-seeking Vietnam-era veterans without PTSD (Gerardi, Keane, Cahoon, & Klauminzer, 1994).

It is problematic to draw conclusions regarding basal physiological state based on data collected prior to a challenge procedure or medical appointment because, as noted elsewhere (Buckley & Kaloupek, 2001; Gerardi et al., 1994; Prins et al., 1995), higher readings for individuals with PTSD may be the result of entering a psychologically threatening situation rather than reflecting a biologically stable elevation in autonomic activation. Thus anxiety generated by anticipation of the trauma-related stimuli may explain the observed elevations in resting psychophysiological levels. One way to address this possibility is to collect physiological data during a laboratory session when participants know that they will not discuss or be exposed to trauma-related material. Very few studies of PTSD have assessed basal psychophysiological levels outside of a context that includes exposure to trauma-related cues. One strategy for circumventing anticipatory arousal is to collect basal readings during a time when individuals are not expecting to confront reminders of their traumatic experience. Two studies that took this approach (McFall, Veith, & Murberg, 1992; Orr, Meyerhoff, et al., 1998) found comparable physiological levels at rest for combat veterans with and without PTSD.

Another approach to assessing tonic physiological levels is to measure activity outside of a laboratory or medical setting. This procedure has the advantage of obtaining measures under relatively natural conditions that may

provide a more accurate representation of individual physiological activity in relation to life activities and stressors. One study has reported higher ambulatory HR levels in a small sample of Vietnam combat veterans with PTSD (Muraoka, Carlson, & Chemtob, 1998). However, two other studies found comparable mean ambulatory (Beckham, Feldman, et al., 2000) or resting (Orr, Meyerhoff, et al., 1998) HR levels in Vietnam combat veterans with and without PTSD. A study that examined HR during sleep also found comparable HR levels in male, inpatient Vietnam veterans with PTSD and normal controls (Woodward et al., 2000).

Buckley and Kaloupek (2001) conducted a meta-analysis of 34 studies that measured baseline or ambulatory cardiovascular activity, including most of those described previously, with the aim of determining whether the research literature as a whole indicates tonic elevations in physiological activity associated with PTSD. The average effect sizes computed across challenge, acoustic startle, and nonchallenge studies indicated higher basal levels for HR and, to a lesser degree, BP shown by individuals with PTSD. Basal HR was highest among studies involving individuals with chronic PTSD, consistent with the hypothesis that elevated basal cardiovascular activity develops over many years, perhaps as the result of adaptation to repeated stress response.

Studies addressing the question of whether PTSD is characterized by persistent arousal have relied on measures of sympathetic nervous system activity, only recently beginning to examine possible parasympathetic contributions. Three studies by Cohen and colleagues (2000; 1998; 1997) have applied spectral analysis to HR data to quantify variability and tease apart the roles of parasympathetic and sympathetic influences with respect to elevated basal HR. These studies involved individuals with PTSD caused by a variety of trauma exposure types. Results show higher resting HR in participants with PTSD relative to controls. This HR difference is accompanied by lower high-frequency (HF) and higher low-frequency (LF) spectral components, indicating that PTSD is characterized by both increased sympathetic tone (LF component) and decreased parasympathetic tone (HF component) under resting conditions. In contrast, Sahar, Shalev, and Porges (2001) reported normal resting parasympathetic tone in PTSD. They found that trauma-exposed individuals with and without PTSD did not differ on measures of respiratory sinus arrhythmia, which is presumed to index vagal (i.e., parasympathetic) regulation of heart rate.

Whether or not PTSD is associated with long-term alterations of sympathetic and/or parasympathetic activity remains unclear; the findings are mixed, even from studies that did not involve exposure to trauma-related materials. If such alterations exist, they seem to develop over time as PTSD becomes chronic and unremitting. A longitudinal study of trauma victims found that the individuals who eventually developed PTSD showed elevated HR resting levels in the emergency room and 1 week later, but the HR levels were no longer elevated and were comparable to those of individuals who did not

develop PTSD at 1- and 4-month follow-ups (Shalev et al., 1998). Thus the initial HR level differences had disappeared even as PTSD became evident and diagnosable. A key question is whether HR levels will again become elevated over time in the subset of individuals who show unremitting PTSD.

The issue of whether there is a long-term alteration of sympathetic activity associated with PTSD is unlikely to be answered by the continued collection of data from small convenience samples in cross-sectional studies primarily designed to test other questions. A stronger scientific strategy is to follow acutely trauma-exposed individuals over an extended period of several years to determine when sympathetic and/or parasympathetic alterations become evident, if at all, and what factors mediate or moderate these changes.

CLINICAL APPLICATIONS OF PSYCHOPHYSIOLOGICAL METHODS

The clinical applicability of psychophysiological findings covered thus far has been primarily in relation to diagnosis. Two other domains of clinical application also have been evident in the literature: prediction of adjustment following trauma exposure and assessment of treatment-related responding.

Predicting Risk and Remission in PTSD

Findings from prospective studies offer some indication that early posttrauma alterations in basal HR may predict the development of PTSD. Resting HR and BP have been measured in studies of miscellaneous trauma survivors (Shalev et al., 1998) and motor vehicle victims (Bryant, Harvey, Guthrie, & Moulds, 2000) during immediate postincident emergency room (ER) or hospital treatment. Both studies found that trauma victims who went on to develop PTSD had significantly higher posttrauma resting HR, but not BP, compared with those who did not develop PTSD. Bryant and Harvey (2002) further reported that five of the original motor vehicle victims who had delayed-onset PTSD (i.e., met diagnostic criteria for PTSD 2 years, but not 6 months, following the traumatic event) also had elevated resting HR levels at the initial posttrauma hospital assessment. Furthermore, Shalev et al. (1998) found comparable resting HR levels between groups with and without PTSD at 1- and 4-month follow-ups, suggesting that only the initial elevation in HR was associated with PTSD risk.

In contrast to findings suggesting that elevated HR shortly after a traumatic event can predict risk of developing PTSD, a study by Blanchard, Hickling, Galovski, and Veazey (2002) found that motor vehicle accident victims with elevated HR levels in the ER were *less* likely to meet criteria for PTSD 13 months after their accidents. The reason for this opposite finding may be due to important methodological differences. In particular, the

Blanchard et al. study recruited individuals seeking treatment for psychological problems related to their accidents approximately 13 months after they occurred, with HR and BP readings obtained retrospectively from ER documents. Selection bias introduced by self-initiated help-seeking may have resulted in a sample that differed in important ways from samples studied by Shalev et al. (1998) and Bryant et al. (2000), which were not limited to individuals who initiated psychological treatment seeking. The Blanchard et al. (2002) study applied an additional restriction that only individuals who were currently symptomatic could be enrolled. Thus sample differences are a credible explanation for the discrepant findings.

Breslau and Davis (1992) conducted a large-scale study of young adults who experienced a traumatic event. They observed that those with chronic PTSD (i.e., lasting 1 year or longer) were more likely to report experiencing psychological and physiological overreactivity to stimuli that symbolized the traumatic event than were individuals who had PTSD that remitted within 1 year. Supporting psychophysiological evidence for this difference in subjective experience comes from a longitudinal study by Blanchard et al. (1996) that examined psychophysiological reactivity in acute trauma victims. In this study, Blanchard and colleagues measured HR and BP responses during trauma-related imagery in individuals who had experienced a recent motor vehicle accident within the previous 1–4 months and then reassessed them 1 year later. Two important findings emerged. First, accident victims with acute PTSD showed greater HR reactivity during trauma-related imagery than those without PTSD, as has been demonstrated consistently in individuals with chronic PTSD. Second, the investigators found that individuals who had PTSD that did not remit within 1 year of the accident produced significantly larger HR responses to the initial trauma-related imagery assessment than individuals who had PTSD that did remit. This latter finding is of substantial importance, because it demonstrates the potential value of early assessment of psychophysiological reactivity for identifying individuals at increased risk for developing chronic PTSD.

Finally, psychophysiology also may have value as a predictor of the clinical course of PTSD. An early study by Meakins and Wilson (1918) exposed soldiers diagnosed with "irritable heart" (probably PTSD) to bright flashes and blank pistol discharges while pulse rate and respiration were monitored. Individuals who showed the larger physiological responses were the ones who were subsequently unable to return to duty.

Assessing Treatment Process and Outcome

The application of psychophysiological methods to treatment-related issues in PTSD remains in its infancy, with only a handful of published studies and case reports. Existing work has focused on two general uses of psychophysiology: tracking of treatment process and demonstration of treatment outcome. Any

of the methods discussed earlier could potentially be used to assess whether or not therapy produces measurable changes in physiological reactivity. Very simply, reactivity to trauma-related cues or startle responses could be assessed prior to, and then following, an intervention to determine the degree of changes associated with treatment. The choice of index would be dictated by the nature of the process of interest (i.e., emotion or attention).

Treatment Process Indicators

Exposure-based therapeutic techniques (e.g., imaginal flooding or desensitization) are particularly well suited to process measurement because of a model of efficacy formulated by Foa and Kozak (1986) that identifies three key markers of therapeutic process: initial response to cue exposure, within-session habituation, and between-session habituation. These markers often are assessed by simply asking a client to provide periodic ratings of subjective distress. In addition to, or instead of, self-reported distress, it is possible to continuously monitor physiological arousal for the same purpose. Accordingly, change in physiological arousal might be used by a therapist to determine how best to proceed in a particular session or between sessions. Particularly during exposure-based treatment, a gradual decrease in physiological arousal might be taken as an indication that specific cues are becoming less distressing for the client. Alternatively, a precipitous decrease in arousal might indicate that the client has disengaged from the task, perhaps because it has become overwhelming (Rachman & Whittal, 1989). In contrast, a gradual increase in physiological arousal could indicate that a client is becoming emotionally engaged in the therapeutic task or, if sustained, it might suggest that the particular therapeutic approach was not having the desired effect.

A few studies have examined the use of psychophysiological measures as indicators of emotional arousal during treatment. Most notably, Pitman and colleagues recorded HR, SC, and facial EMG during imaginal flooding treatment (Pitman, Orr, Altman, Longpre, Poire, Macklin, et al., 1996). Strong trends were observed for relationships between both within-session HR habituation ($r = .51$, $p < .05$) and between-session HR habituation ($r = .46$, $p < .05$) and reduction in number of daily intrusion symptoms. In contrast, a study that examined treatment of combat-related PTSD using eye movement desensitization and reprocessing (EMDR) therapy did not show these relationships between process indicators and outcome (Pitman, Orr, Altman, Longpre, Poire, & Macklin, 1996). The reason for the difference in findings is not clear, but a recent direct comparison of prolonged exposure and EMDR found that prolonged exposure was more effective in reducing reexperiencing (which includes intrusive recollections of the traumatic event) and avoidance symptoms than EMDR (Taylor et al., 2003). Such evidence raises the intriguing possibility that physiological indicators of therapy process have unique information value in relation to therapeutic process.

Treatment Outcome Indicators

Change in physiological reactivity to trauma-related cues from before treatment to after treatment may provide a useful index of clinical improvement both for group comparisons and individual cases. For example, it can be used to compare the efficacy of one therapy relative to another, or it might be used to determine whether or not a therapy has had the desired effect for a given client. Whatever its potential, use of psychophysiological methods to assess treatment outcome remains a relatively unexplored area in the PTSD literature, with only a few published reports to date. An early case report of combat-related PTSD treated with imaginal flooding by Keane and Kaloupek (1982) demonstrated that improvement was associated with a reduction in HR response magnitude during subsequent recollection of the trauma. Shalev, Orr, and Pitman (1992) found psychophysiological responses during trauma-related imagery to be sensitive to psychiatric improvement following a systematic desensitization procedure. Similarly, Boudewyns and Hyer (1990) reported that decrease in SC response to trauma-related imagery following treatment was associated with a higher "adjustment" score at 3 months posttreatment.

The measurement of HR variability before and after a 4-month course of treatment with the medication fluoxetine was used by Cohen and colleagues (Cohen, Kotler, Matar, & Kaplan, 2000) to assess change in sympathetic and parasympathetic tone and to examine the relationship of such change to improvement in PTSD-related symptoms. An uncontrolled trial by Tucker et al. (2000) found that 10 weeks of treatment with a similar medication, fluvoxamine, produced subjective symptom improvement and showed reduced physiological reactivity to trauma-related imagery by the PTSD patients. Although suggestive, this positive finding must be interpreted with caution, because there is clear evidence that reactivity to trauma-related cues is decreased on a second testing occasion, even when there is no intervening treatment (Blanchard et al., 1996; Keane et al., 1998). Nonetheless, evidence suggests the utility of psychophysiological reactivity as an index of treatment outcome.

There is preliminary evidence suggesting that change in P3 amplitude may provide a useful gauge of a patient's response to treatment with psychotropic medication. Although no studies have directly examined the effects of psychotropic medications on P3 amplitudes in PTSD, one study has reported normal P3 amplitudes in medicated, but not unmedicated, patients with PTSD (Metzger, Orr, Lasko, & Pitman, 1997). Such normalizing effects of medications on P3 amplitude have been reported for other clinical disorders, including depression and attention-deficit/hyperactivity disorder (ADHD). Additionally, increases in P3 amplitude following methylphenidate treatment were found to successfully predict the long-term benefits in children with ADHD (Young, Perros, Price, & Sadler, 1995). Thus assessment of P3 response amplitude appears to hold promise for both predicting and evaluat-

ing the efficacy of psychotropic intervention in various clinical disorders (Polich & Herbst, 2000), including PTSD.

APPLICATION OF PSYCHOPHYSIOLOGICAL METHODS TO BASIC PROCESSES

Unconditioned or Defensive Response and Habituation

Autonomic Measures

Similar to startle, a second approach to studying psychophysiological reactivity involves administration of multiple presentations of the same high intensity stimulus, most often a 95-decibel, 500-millisecond, pure tone with 0-millisecond rise and fall times (Orr, Lasko, Shalev, & Pitman, 1995; Shalev, Orr, Peri, Schreiber, & Pitman, 1992). Heart rate and SC responses to the stimulus presentations have been measured, along with eyeblink EMG, to provide indices of autonomic reactivity to the high intensity stimuli. It is important to note that these studies have used stimuli with longer durations than have studies focusing exclusively on EMG startle (e.g., Butler et al., 1990), because longer duration may produce a particular type of physiological reaction termed a defensive response (e.g., Graham, Anthony, & Zeigler, 1983, p. 392) in addition to startle, whereas shorter duration stimuli (< 500 milliseconds) may not produce the defensive component. Response scores for each trial are computed by subtracting the mean level immediately preceding tone onset from the maximum increase in level within a prespecified window following the tone. Because there are differences in the latencies of response onsets, the window is longer for autonomic (1–4 seconds) than for eyeblink (20–200 milliseconds) responses.

An advantage of using a single intensity level is that it allows for examination of decline in response magnitude across trials. This habituation of responding reflects the ability to learn *not* to respond to repetitive stimuli, essentially learning to ignore irrelevant information. Habituation is commonly measured in two ways: absolute and relative. Absolute habituation measures the number of trials required to reach a prespecified criterion for nonresponse, such as two successive trials for which there is no response (or an extremely small one). Relative habituation, on the other hand, measures the rate of decline (i.e., steepness of the slope) in response magnitude across a given set of trials.

The magnitudes of autonomic responses to repeated presentations of intense (i.e. loud) auditory stimuli have been found to be greater in individuals with PTSD. Specifically, they produce larger HR responses and/or show a slower rate of decline of SC response magnitude than individuals without PTSD (Metzger et al., 1999; Orr, Lasko, Metzger, & Pitman, 1997; Orr et al., 1995; Orr, Solomon, Peri, Pitman, & Shalev, 1997; Paige, Reid, Allen, & Newton, 1990; Rothbaum, Kozak, Foa, & Whitaker, 2001; Shalev et al.,

1992; Shalev et al., 2000; Shalev, Peri, Orr, Bonne, & Pitman, 1997). To date, only two studies have failed to find evidence for larger HR responses to loud tones in individuals with PTSD (Rothbaum et al., 2001; Shalev et al., 1997). However, both of these studies did show slower absolute SC response habituation in individuals with PTSD.

Findings in identical twins indicate that that there are strong genetic determinants of responsivity and habituation for both HR (Boomsma & Gabrielli, 1985; Carroll, Hewitt, Last, Turner, & Sims, 1995; Ditto, 1993; Kotchoubei, 1987) and SC (Lykken, Iacono, Haroian, McGue, & Bouchard, 1988). The possibility that the greater HR reactivity and slower decline of SC responses observed in individuals with PTSD may reflect a constitutional risk factor rather than a consequence of trauma was addressed in a recent twin study of Vietnam combat veterans and their identical twin brothers who did not serve in Vietnam. The findings from this study clearly demonstrate that, whereas veterans with combat-related PTSD showed elevated HR responding to startle-producing tones, their genetically identical twin brothers did not (Orr et al., 2003). In addition, a prospective study (Shalev et al., 2000) found that, although trauma victims who went on to develop PTSD showed elevated HR responses to startle-producing tones at 1- and 4-month posttrauma assessments, they did not show these elevated responses at a 1-week posttrauma assessment. Together, these findings provide compelling support for the position that larger HR responses to sudden, loud tones in individuals with PTSD represent an acquired, rather than a preexisting, condition. In contrast to the acquired nature of larger HR responses, the Orr et al. (2003) study also provided suggestive evidence that slower relative SC response habituation reflects a pretrauma vulnerability factor for PTSD. More specifically, both veterans with PTSD and their brothers showed a tendency toward slower SC habituation compared with that shown by the veterans without PTSD and their brothers.

It is important to note that heightened psychophysiological reactivity to intense auditory stimuli is not unique to PTSD; individuals with other types of anxiety disorders show increased reactivity as well. For example, studies of generalized anxiety disorder (GAD), agoraphobia, social phobia (Lader, 1967; Lader & Wing, 1964), and panic disorder (Roth, Ehlers, Taylor, Margraf, & Agras, 1990) have observed a slower decline in SC responses to repeated presentations of intense auditory stimuli for the groups with anxiety disorder.

Electrocortical Measures

Responses to high-intensity stimuli also have been studied by measuring cortical activity, particularly P2 response amplitude, to tones of varying intensity levels. In this work, cortical activity is typically recorded from the central midline (Cz) site while participants passively listen to the random presentations of 74-, 84-, 94-, and 104-decibel tones having rise and fall times of 25 milliseconds (Metzger et al., 2002; Paige et al., 1990). EEG is recorded begin-

ning 100 milliseconds prior to tone onset and ending 500 milliseconds after tone onset. The EEG data from each trial are averaged separately for each tone intensity level, and the P2 response peak (the most positive point between approximately 140 and 230 millisecond posttone onset) is determined for the averaged waveform for each stimulus intensity level. Slope for the P2 response is then calculated from the regression line of the P2 response peaks across tones of increasing intensity.

Studies of electrocortical responses to intense stimuli provide additional evidence consistent with heightened defensive responses in individuals with PTSD. Two ERP studies (Lewine et al., 2002; Paige et al., 1990) found that, when exposed to tones of increasing intensity, male combat veterans with PTSD produced decreased P2 amplitudes to higher intensity tones (i.e., a decreased P2 slope or so-called "reducing" response). This pattern differed from that observed in combat veterans without PTSD and other normal participants, a pattern that reflects the typical "augmenting" whereby P2 amplitudes get progressively larger to louder tones. Paige et al. (1990) interpret the propensity to show diminishing P2 response amplitudes in PTSD as a state of protective inhibition. In other words, the nervous system is thought to have heightened sensitivity to stimulation, to which it adapts in self-protective fashion by dampening the impact of the increasingly loud tones.

Two studies contrast with the electrocortical "reducing" findings. A study of female veterans who served as nurses in Vietnam used a procedure nearly identical to that employed by Paige et al. (1990) but found increasing, rather than decreasing, P2 response amplitudes to tones of increasing intensities for participants with PTSD (Metzger et al., 2002). Finally, children with PTSD resulting from physical and/or sexual abuse also were found to produce increased P2 response amplitudes to progressively louder tones compared with abused children without PTSD (McPherson, Newton, Ackerman, Oglesby, & Dykman, 1997). Interpretation of this finding is complicated by the fact that the paradigm used with children deviated substantially from the passive-listening paradigm used in studies with adults in that the children were required to make a button-press response to all tones and were provided with feedback and a monetary award for responding quickly and without blinking.

Conditionability

Conditionability refers to the tendency to acquire and resist extinction of conditioned responses. Individual differences in this characteristic have been offered as one explanation for the fact that only some of the individuals who are exposed to a traumatic event go on to develop PTSD. In a test of this model, Orr and colleagues (Orr et al., 2000) randomly presented participants with two different-colored circles on a computer monitor. One of the colored circles (CS+) was paired with a highly annoying, but not painful, 500-millisecond electric shock (unconditioned stimulus; UCS), whereas the other colored circle (CS-) was not. Individuals with PTSD resulting from various traumas

demonstrated larger HR, SC, and facial EMG responses to CS+ compared with CS- trials during the acquisition phase when only the CS+ was paired with the UCS. They also demonstrated larger differential SC responses during an extinction phase in which participants were told they would no longer receive the electric shocks. These findings suggest that individuals with PTSD acquire a larger and more persistent conditioned autonomic response to an aversive stimulus.

Two other studies failed to find evidence for increased conditionability among individuals with PTSD. In one, Gulf War veterans with PTSD actually were slower than those without PTSD in acquiring a conditioned response to a CS+ paired with a mild electric shock UCS (Grillon & Morgan, 1999). This study used eyeblink response to a startle probe presented in the context of CS+ and CS- rather than autonomic measures to assess conditioned response strength. It is noteworthy that veterans with PTSD demonstrated increased eyeblink during both CS- and CS+ training trials, suggesting a generalized fear response. A second study of mixed trauma victims used a loud noise as the UCS and recorded both SC and HR responses to CS+ and CS- presentations (colored slides) to assess CR strength. Individuals with PTSD produced larger SC responses during the extinction phase to both CS+ and CS- trials, but they did not show a larger differential fear response (Peri et al., 2000). The explanation for these discrepant findings is not clear, but it may well be related to differences in both experimental methods and dependent measures.

Assessing Emotional and Clinical States

Emotional and motivational states have been studied in both clinical and normal populations using electrophysiological measures of cortical arousal. This research is based on neuropsychological models relating different patterns of brain activity to psychologically significant states. In their simplest form (Davidson, 1984; Heller, 1990), these models contend that greater activation of the left than the right frontal hemisphere is associated with positive emotional states and approach-related motivational tendencies, whereas relatively greater activation of the right frontal hemisphere is associated with negative emotional states and withdrawal-related tendencies. Although findings from a number of studies support this positive-left/negative-right link, a subset of studies report inconsistent, and even contradictory, results. Of special note are recent studies showing that greater left-sided frontal activation is associated with negative emotional states, specifically anger (Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001) and anxiety (Heller, Nitschke, Etienne, & Miller, 1997). Such findings have led researchers to revise original asymmetry models in favor of more complex ones. For example, Heller and colleagues (Heller et al., 1997) have proposed that negative emotional states, including anxiety subtypes, are associated with unique patterns of regional brain activation. Specifically, "anxious apprehension" (i.e., rumination and worry) is associated with greater left-sided frontal activity, whereas "anxious

arousal" (i.e., physiological arousal and hyperreactivity) is associated with greater right-sided activity, particularly in tempoparietal regions.

To date, two studies have examined the relative activation of the left versus the right hemisphere in individuals with PTSD. In a study of male Vietnam combat veterans, those with PTSD and no comorbid major depression showed greater left-sided frontal activation than veterans without PTSD (Metzger et al., 1998). Although greater left-sided frontal activation has been found to be associated with anger and, therefore, might represent increased irritability and anger in PTSD (criterion D2), this pattern also can be viewed as consistent with anxious apprehension in PTSD. A second study examined the relationship between PTSD symptom severity and patterns of regional (frontal, temporal, and parietal) brain asymmetry in female Vietnam nurse veterans with current, lifetime, or no PTSD (Metzger et al., in press). In contrast to the findings for male combat veterans, measures of PTSD symptom severity were not related to frontal asymmetry. However, severity of PTSD-related arousal symptoms was associated with increased right-sided parietal activation. Although different, the findings from both studies support the contention that particular patterns of asymmetrical brain activation are associated with negative states of emotion or arousal and encourage further application of this electrophysiological approach to the study of PTSD.

POTENTIAL INFLUENCES ON THE QUALITY AND VALIDITY OF ASSESSMENT

Appropriateness of Trauma Cue Presentations

A critical factor potentially accounting for part of the imperfect association between psychophysiological reactivity and PTSD diagnosis (e.g., Keane et al., 1998) is cue adequacy. A question that must be addressed each time a trauma-related psychophysiological challenge is administered concerns how well the stimulus material matches the individual's traumatic event. In this respect, there may be an advantage to idiographic approaches to trauma cue selection. Although standardized presentations benefit from uniformity and their potential for allowing tight experimental control, they suffer the disadvantage of variable correspondence with individual experience. Idiographic presentations may be designed to closely approximate the internal (memory) representations of the traumatic experience and thereby improve the validity of assessment.

Compliance with Protocol Demands

Any psychophysiological protocol requires that participants understand and adhere to a particular set of demands. The complexity of these demands will be determined by the nature of the protocol and the physiological measures being obtained. Validity and interpretability of the psychophysiological data will be significantly influenced by the degree of compliance. Even simple tasks,

such as listening to a series of tones, require that individuals sit quietly and keep their eyes open. Although these may appear to be modest requirements, they can be challenging for an individual who is, for example, very anxious. More complex tasks may make significant demands on the physical and cognitive abilities of even well-functioning individuals, including the need to understand and remember a detailed set of instructions, concentrating and focusing attention for a sustained period, discriminating among several different types of stimuli, and staying motivated to perform a task despite the fact that it is repeated for tens or hundreds of trials. Of particular importance to trauma-related assessment are the emotional demands of the task. It may be very difficult for individuals to remain engaged in a procedure that produces significant emotional discomfort, as when they are exposed to reminders of a traumatic event. Individuals may try to reduce distress by averting their gaze from a visual stimulus or by distracting themselves when they are supposed to be vividly recalling an upsetting experience. Emotional distress may cause an increase in motor activity, such as fidgeting, that can artificially elevate physiological activity.

Occasional deviations from a protocol are inevitable; therefore, it is routine to plan ways to identify them and assess their impact. It is important to have some means for monitoring an individual as he or she goes through the assessment protocol. A closed-circuit video system can be used to observe gross body movements or to verify that an individual is generally complying with task demands. A former research participant decided to use the initial baseline-recording period of a study as an opportunity to clean out his wallet, even though he had been previously instructed to sit quietly. A glance at the closed-circuit TV monitor made it clear why the physiological measures had suddenly become erratic. Emotional provocation or challenge testing also offer unique opportunities for observing an individual during exposure to trauma-related cues, offering another reason that it is advantageous to have some means by which the individual can be unobtrusively observed. Although individuals' failure to comply with task demands, such as viewing or vividly recalling trauma-related materials, may reduce the interpretability of psychophysiological data, it also may be clinically informative as a form of behavior relevant to their PTSD.

Dissociation

It is possible that some psychological traits or response dispositions serve to decouple the relationship between subjective emotional experiences and psychophysiological reactivity. For example, individuals with dissociative tendencies may show reduced physiological reactivity to trauma-related stimuli, even though they report a high level of PTSD-related symptoms. The tendency to dissociate could partially explain the roughly 40% of individuals who meet full DSM criteria for PTSD despite being physiologically nonreactive. In a demonstration of this point, Griffin, Resick, and Mechanic (1997) assessed

physiological reactivity in women who had developed PTSD following sexual assault and found that women who retrospectively reported greater peritraumatic dissociation (depersonalization) at the time of the rape were less physiologically reactive while describing the experience in detail compared to women who reported less dissociation. However, the negative relationship between self-reported peritraumatic dissociation and psychophysiological reactivity in the laboratory was not replicated in a recent study by Kaufman et al. (2002). This work was based on secondary analysis applied to the very large data set available for the multisite study in which Keane et al. (1998) conducted challenge testing with male Vietnam combat veterans. One potentially important difference between this study and the one by Griffin and colleagues is the chronic nature of PTSD in the veteran sample and the contrasting acute nature of PTSD among the assault victims.

More broadly, chronic depersonalization disorder has been found to be associated with smaller SC reactivity to unpleasant pictures (Sierra et al., 2002). And, in contrast to the findings of decreased physiological reactivity, results from a study of individuals who had previously suffered a serious cardiac event suggest that reactivity may be increased in individuals who report high peritraumatic dissociation (Ladwig et al., 2002). Individuals who retrospectively reported high dissociation were found to produce larger SC and eyeblink EMG responses to startling tones than individuals who reported little or no peritraumatic dissociation. Within the group that reported high peritraumatic dissociation, comparisons between individuals with full or partial PTSD and those without PTSD yielded significantly larger EMG, but not SC, responses to the loud tones in the PTSD subgroup.

Dissimulation

Available evidence is limited on the issue of faking in the context of PTSD-related psychophysiological assessment. A study by Gerardi, Blanchard, and Kolb (1989) showed that veterans with PTSD were unable to significantly alter their responses when instructed to do so, whereas veterans without PTSD were able to increase their physiological reactivity so as not to differ from those with PTSD on several measures. On the other hand, a high level of correct classification regarding true PTSD status was obtained when a previously used HR cutoff score was combined with baseline HR level as predictors. Similarly, Orr and Pitman (1993) instructed a group of veterans without PTSD to try to increase their reactivity during trauma-related imagery so as to appear as though they had PTSD. A discriminant function based on SC and corrugator EMG responses accurately classified 16 of 16 veterans when they were not trying to simulate PTSD and 12 of the 16 veterans when they were attempting to simulate PTSD, this despite the fact that during simulation these veterans were able to produce HR responses as large as those of individuals with PTSD.

A study of PTSD related to the missile attacks on Israel during the Gulf War of 1991 (Laor et al., 1998) examined HR, BP, and forehead EMG responses to audiotape presentations of various experiences, including a set of stimuli associated with a missile attack (e.g., alert siren, emergency code words, and missile explosion). Participants were asked to try to "fake" their physiological responses by either increasing them (non-PTSD group) or preventing them from increasing (PTSD group) during a second presentation of the missile-attack audiotape. Contrary to the findings of Gerardi et al. (1989), the non-PTSD group was unable to significantly increase their physiological responses during the simulation, whereas individuals with PTSD were able to significantly decrease their responses when instructed to do so. Taken together, these findings suggest some potential for dissimulation but indicate that it is difficult for individuals without PTSD, as a group, to reliably simulate the pattern of physiological responses of individuals with PTSD.

Individual Biological Influences

A variety of factors that can influence psychophysiological reactivity arise from characteristics such as age, sex, skin pigmentation, continental race, menstrual cycle phase, and physical fitness level. Although relationships to autonomic activity have been established in the general psychophysiological literature, there are few examples from the trauma literature that directly examine the impact of these factors. One study by Shalev et al. (1993) did find that female participants with PTSD demonstrated 33% (albeit nonsignificantly) greater physiological responding to their trauma script than males with PTSD. This example raises the question of whether such differences are sex related per se or the result of covarying influences such as differences in types of trauma exposure between men and women. More work like this can be expected as the literature on the psychophysiology of trauma develops.

Pharmacological Agents

Central and peripheral physiological levels and responses can be strongly influenced by a variety of substances, including prescribed and nonprescribed medications, alcohol, caffeine, and nicotine. For example, beta-blocking agents that are commonly prescribed for hypertension can reduce cardiovascular activity level and attenuate reactivity (Fredrikson et al., 1985). The anticholinergic drugs that are commonly used to treat depression can produce a substantial elevation in resting HR level. As noted previously, psychotropic medications have been found to normalize ERP components, particularly P3 amplitude, in clinical samples (Metzger, Orr, Lasko, & Pitman, 1997). Unfortunately, little is known about the impact of many of the medications on psychophysiological responding, making it difficult to estimate their impact.

Although it is not often possible to perform clinical psychophysiological testing on individuals in a medication-free state, on occasion such testing may be coordinated with a change in medication and may take place prior to beginning a new regimen. This assumes that the biological half-life of the discontinued medication is relatively short. In some instances, it may be possible to use physiological measures that are not influenced by a particular medication. For example, Fredrikson et al. (1985) found that measures of cardiovascular activity and reactivity were influenced by a beta blocker but that SC level and reactivity were not. In research it may be possible to obtain a subgroup of medication-free individuals who can be compared with those taking medications, as well as with the control group(s). Such subgroup comparisons can provide effect size estimates to guide determinations of whether medications are having a substantive effect on the measures of interest. Medication use by patients or participants should be noted as a matter of course, so that this information is available for subsequent consideration (e.g., to account for anomalies in responding).

Nicotine, caffeine, and alcohol are commonly used substances that also can influence physiological systems. Unfortunately, they do not have uniform impact across physiological systems, and the effect of withdrawal can be as problematic as that of consumption (Hughes, 1993; Lane & Williams, 1985; Lyvers & Miyata, 1993; Perkins, Epstein, Jennings, & Stiller, 1986; Ratliff-Crain, O'Keeffe, & Baum, 1989). For example, it is a common practice to ask individuals to abstain from using nicotine or caffeine for a period of time (often 30 minutes or more) prior to testing. However, some individuals may find that even brief abstinence produces discomfort, and it is difficult to know how this will influence test results. Despite uncertainty about how to adjust for their effects, it is typically a good idea to obtain estimates of an individual's daily consumption of nicotine, caffeine (coffee and soda), and alcohol prior to testing.

POTENTIAL CONCEPTUAL INSIGHTS

Relationshiop between PTSD and Other Disorders

Much of the preceding discussion has focused on psychophysiological methods applied to questions of clinical interest. In addition, psychophysiological data can provide evidence for conceptual models concerning the nature of PTSD. For example, it may be noteworthy that the heightened physiological reactivity to trauma-related stimuli observed in PTSD is similar to that observed when phobia-related cues are presented to individuals with simple phobia (Cook et al., 1988; McNeil et al., 1993). Simple phobics show larger HR and SC responses during imagery of their phobic objects than do other anxious groups who have less specific fears, such as agoraphobics. In fact, individuals with agoraphobia have been found to be physiologically unresponsive during imagery of their fear-related contexts (Cook et al., 1988; Zander &

McNally, 1988). An important factor in determining or modulating physiological reactivity across various anxiety disorders appears to be the specificity of the fear. In terms of Lang's (1985) bioinformational theory of emotion, the memory networks associated with specific fears may be more readily or strongly activated than less specific fears because the external cues used to trigger the fear are more closely matched with its internal representation. Thus both PTSD and simple phobia would appear to have fear networks that are highly specific and thereby easily activated.

Whereas the specificity of responses to trauma-related cues suggests a similarity with simple phobia, the findings of slower habituation of SC responses to intense auditory stimuli (Orr et al., 1995; Shalev et al., 1992) suggest a similarity with disorders characterized by more diffuse forms of anxiety. Interestingly, one study (Lader, 1967) that included a group of individuals with simple phobia reported that they did not differ from nonanxious individuals in their rate of SC habituation. Also, as noted earlier, both PTSD and panic disorder have been found to be associated with an elevated eyeblink startle response. Increased P50 ratio (Gillette et al., 1997) and reduced P3 amplitude (McFarlane et al., 1993) observed in PTSD also have been observed for other disorders, including schizophrenia and depression. Polich and Herbst (2000) described the P3 component of ERP as a general, but nonetheless utilitarian, measure of "cognitive efficiency that reflects how well an individual's CNS can process and incorporate incoming information" (p. 6). The nonspecificity of these findings suggests that various clinical disorders may share similar sensory and cognitive impairments. Taken together, these psychophysiological studies provide information that may be important in shaping the conceptualization of PTSD as an anxiety disorder, as well as identifying features that it shares with other disorders outside the anxiety spectrum.

Underlying Biological and Psychological Mechanisms of PTSD

The possibility that exaggerated startle in PTSD is a context-dependent phenomenon reflecting activation of the corticotropin-releasing hormone (CRH) system of the bed nucleus of the stria terminalis is consistent with evidence suggesting that patients with PTSD show elevated levels of CRH in the cerebrospinal fluid (Baker et al., 1999; Bremner et al., 1997) coupled with low basal levels of cortisol, a hormone that inhibits the production of CRH (Yehuda, 2002). Considered in conjunction with evidence that CRH potentiates startle (Lee & Davis, 1997; Swerdlow, Britton, & Koob, 1989) and that hydrocortisone administration attenuates startle (Buchanan, Brechtel, Sollers, & Lovallo, 2001), these findings point to a possible link between the symptom of exaggerated startle and hypothalamic–pituitary–adrenal-axis abnormalities in PTSD.

A second potentially fruitful avenue for research might be to examine whether the laboratory-based demonstration that baseline startle amplitude is

context dependent can be validated by the "real world" experience of patients with PTSD. That is, does exaggerated startle occur primarily in specific situations or contexts, and, if so, what defines them? To do so, it may be necessary to conduct ambulatory assessment of startle responding and develop instruments for assessing self-reported startle with increased temporal resolution. Research along these lines has the potential to clarify the discrepancy between findings from self-report versus psychophysiological studies of exaggerated startle and to shed light on the mechanisms underlying this symptom.

Finally, decreased P3 response amplitude is popularly interpreted as indicative of attention-related difficulties. Yet Felmingham et al. (2002) found that reduced P3 response amplitudes were associated with increased numbing symptoms in their study of assault and accident victims. It is possible that reduced P3 response amplitude in PTSD reflects disinterest or lack of emotional engagement with a task, rather than a primary disturbance in attention. The fact that female Vietnam nurse veterans with PTSD showed larger, rather than smaller, P3 response amplitudes (Metzger et al., 2002) additionally brings into question the primary psychological mechanism related to this cortical response abnormality. However, it is possible that the modulation of the P3 response in the nurse veterans was related to increased, as opposed to decreased, emotional engagement. The authors speculate that the larger P3 amplitude responses shown by this high-functioning PTSD sample might represent an effortful "overcompensation" of attention resources to ensure successful performance of the task (Metzger et al., 2002). It will be important for future research to address alternative psychological factors that potentially mediate this cortical response abnormality in PTSD.

A RECOMMENDATION FOR RESEARCH AND CLINICAL PRACTICE

Reliance on interview-based self-report as the means for establishing a formal PTSD diagnosis (e.g., according to DSM-IV criteria) is standard for mental disorders and is practical in terms of applicability. On the other hand, PTSD is relatively unique among the diagnostic categories for mental disorders in requiring specification of the experience that is presumed to have caused symptoms to develop. Although this requirement can be cumbersome and can precipitate diagnostic ambiguities, it also can be viewed as a positive reflection of the knowledge base on which the diagnostic criteria for PTSD have developed. Which is to say, if we knew the experiences that cause depression or schizophrenia, this information would likely be included as part of the diagnostic criteria for these disorders, too. In order to further extend PTSD as a model diagnostic entity, it may be time to consider refining the criteria to make them less dependent on subjective evidence. In particular, we propose that the accumulated findings from studies using trauma-relevant challenge tasks are sub-

stantial enough to justify a greater role for direct psychophysiological evidence in the diagnostic determination.

Relocation of the DSM symptom concerned with physiological reactivity to trauma cues from the arousal category (D) to the reexperiencing category (B) was a first step in this direction. However, although it captures the emphasis on evocation of emotion-related physiological reactions, it still allows the evidence to remain subjective. This latitude seems unnecessary given the accumulation of psychophysiological findings and, as we have noted earlier, the increased availability of relatively inexpensive and easy-to-use physiological recording devices. Furthermore, there is already a subjective symptom option in category B referenced to "intense psychological distress" upon exposure to trauma cues (B4), which potentially overlaps with the content of symptom B5. Given the fact that only one B symptom is required for the PTSD diagnosis, these symptoms appear to be redundant as subjective complaints.

An alternative approach might be to separate the inherently subjective symptoms in category B (B1–4) from symptoms that can be demonstrated by objective physiological reactivity (B5). Consistency with the current diagnostic standard could be maintained by requiring one symptom from the B1–4 group *or* concrete psychophysiological evidence consistent with B5. Among the advantages of this approach is that it preserves the possibility that some individuals who may have difficulty reporting on their subjective state (e.g., young children; certain stroke victims) would still have a means for providing evidence of reexperiencing.

This call for a limited application of psychophysiological methods to document physiological arousal to trauma reminders does not add a new requirement for the presence of physiological reactivity to confer the diagnosis of PTSD. It can, however, serve as a starting point for refinement of the diagnostic standard for PTSD and can stimulate new avenues of empirical study that may lead to such a development. Exaggerated startle response (D5) is another symptom that may eventually warrant consideration of formal physiological documentation, but the current evidentiary base for this change is not as well developed as that for physiological reactivity. It should be added that this proposal is not intended as an endorsement of the taxonomic approach to PTSD diagnosis; it merely recognizes the important role that DSM plays in providing standardization for the study and treatment of the disorder, given the limits of our knowledge about the enduring impact of traumatic stress.

CONCLUSION

Psychophysiological assessment sometimes has an exaggerated image as a truly objective means for detecting an individual's psychological or emotional state. Although psychophysiological measures and methods can provide unique information, they are not inherently more valid or objective than typi-

cal assessment methods involving self-report or interviews. It is usually necessary to interpret psychophysiological information in the context of evidence collected via these other assessment methods. Because it is not uncommon for psychophysiological assessments to provide ambiguous evidence about diagnostic status or psychological state just as other methods do, there is often no choice but to rely on convergence from multiple sources of evidence. Even so, divergence between different sources of information can be highly informative and can provide clinical guidance. For example, an individual who reports that he or she is not bothered by reminders of a previous traumatic event yet who shows heightened physiological reactivity in the laboratory when recalling the event may be unaware of or denying the impact that this event is having on his or her emotional well-being. On the other hand, an individual who shows a generalized pattern of high distress reporting (e.g., one of the so-called "overreporters") may be more easily engaged in constructive clinical dialogue about his or her reporting style when presented with evidence that his or her physiological reactivity is not consistent with his or her subjective experience.

To date, most PTSD-related psychophysiological research has focused on demonstrating differences between groups of individuals with and without PTSD. Although this work has contributed substantially to the conceptual understanding of the disorder, the evidence for group differences rarely has direct value for the clinician and individual patient. This disjunction between laboratory and clinic reflects the fact that little effort has been devoted to the translation of research findings into clinically useful applications. For example, although a number of studies have demonstrated greater physiological responses to trauma-related stimuli, larger eyeblink startle, and reduced P3 responses in groups of individuals with PTSD, they provide little guidance for determining whether the physiological responses of a given individual are "heightened," represent an "exaggerated" startle response, or reflect "disturbed" attention. Perhaps future diagnostic criteria will offer standards for determining whether a particular response represents a clinically meaningful elevation or diminution. The research that is required in order for this to happen fits with a major challenge facing health care in the United States and worldwide concerning the need for increased efforts to translate laboratory and preclinical research into clinical advances (Fontanarosa & DeAngelis, 2003; Sung et al, 2003). It is encouraging that the blossoming of evidence regarding psychophysiology and PTSD over the past 10 years may now have reached the point at which it can provide a suitable base from which to pursue this translational goal in the trauma field.

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